

# Polytechnic UNIVERSITY

GRANT / HQ.

11-46 - CR

48313

7P.

WEBER RESEARCH INSTITUTE

POLY-MRI-1454-86  
December 1986

## FINAL TECHNICAL REPORT

on

## A STUDY OF LARGE, MEDIUM AND SMALL SCALE STRUCTURES IN THE TOPSIDE IONOSPHERE

Submitted by

Stanley H. Gross  
Spencer P. Kuo  
Jerry Shmoys

(NASA-CR-180068) A STUDY OF LARGE, MEDIUM  
AND SMALL SCALE STRUCTURES IN THE TOPSIDE  
IONOSPHERE Final Technical Report  
(Polytechnic Inst. of Brooklyn) 7 p

N87-17413

Unclas  
CSCL 04A G3/46 43680

Prepared for

National Aeronautics Space Administration  
under  
Grant NAGW284

# A STUDY OF LARGE, MEDIUM AND SMALL SCALE STRUCTURES IN THE TOPSIDE IONOSPHERE

## Abstract

The program was primarily concerned with the study of ISIS and Alouette data for large, medium and small scale structures in the ionosphere. It also sought correlation with measurements by other satellites, such as the Atmosphere Explorer C and E and the Dynamic Explorer 2 satellites, of both neutrals and ionization, and with measurements by ground facilities, such as the incoherent scatter radars.

Large scale coherent wavelike structures were found from ISIS 2 electron density contours from above the F peak to nearly the satellite altitude ( $\sim 1400\text{km}$ ). Such structures were also found to correlate with the observations by AE-C below the F peak during a conjunction of the two satellites. Vertical wavefronts found in the upper F region suggest the dominance of diffusion along field lines as well. This work was presented at the Ionospheric Effects Symposium in Arlington, Virginia in May, 1984.

Prof. Gross, with Mr. D.B. Muldrew of CRC, Ottawa, Canada, also discovered multiple, evenly spaced field-aligned ducts in the F region that, at low latitudes, extend to the other hemisphere and are in the form of field-aligned sheets in the east-west direction (perhaps resolving an old question as to the shape of ducts). Further statistical interpretation of the uniformly spaced ducts, observed in a year of ISIS 2 data, has been reported at the URSI meeting in Boulder, Colorado in January, 1984. Another paper presented there, with Prof. Gross collaborating with Prof. Kuo of the Polytechnic, and Dr. Lee of the Regis College Research Center in Weston, Massachusetts, suggests a parametric instability with a gravity wave as the source to explain the duct structure.

Low latitude heating events were discovered that could serve as sources for waves in the ionosphere. Prof. Gross presented a paper on this work at the International Symposium on Equatorial Aeronomy in Hong Kong in March, 1984.

## Publications

The following papers were published as a result of this and allied efforts:

1. S.H. Gross and D.B. Muldrew, "Uniformly Spaced Field-Aligned Ionization Ducts," J. Geophys. Res., *89*, 8986-8996, 1984.
2. S.H. Gross, C.A. Reber and F.T. Huang, "Large Scale Waves in the Atmosphere Observed by the AE-C Satellite," IEEE Trans. Geosci. Rem. Sen., *GE-22*, 340-352, 1984.
3. S.H. Gross, "Global Large Scale Structures in the F Region," Proc. of the Thermosphere Dynamics Workshop II, NASA Conference Publication 2389, October 3-5, 1984.
4. S.H. Gross, "Global Large Scale Structures in the F Region," J. Geophys. Res., *90*, A1, 553-558, January 1985.
5. S.H. Gross and F.T. Huang, "Medium Scale Gravity Waves in the Thermosphere Observed by the AE-C Satellite," IEEE Trans. Geosci. Rem. Sens., *23*, #2, March 1985.
6. S.H. Gross, "Large Scale Wave Structures from Topside Sounding," Radio Science, *20*, #3, 499-510, May-June 1985.
7. S.H. Gross, "Unusual Heating Events at 250 km Altitude at Very Low Latitudes Seen by AE-E," J. Atm. Terr. Phys., *47*, 941-944, Aug.-Oct., 1985.

## I. Introduction

Historically, large and medium scale structures were first observed in the ionosphere by ground based sounders (Munro, 1950) and later by incoherent scatter radars (Thome, 1968). These structures are called traveling ionospheric disturbances (TID's). More recently such structures were observed by satellite in situ measurements of both neutrals and ionization (Dyson et al., 1974; Reber et al., 1975). Gross et al., (1980, 1984, a and b), and Gross (1984) using Atmosphere Explorers AE-C and -E in situ data showed that neutrals and plasma may be closely coupled at an altitude of 250 km over a large range of scale sizes from tens to thousands of kilometers.

Ground based sounders measure ionization below the F-layer peak. Networks of these sounders have identified large scale structures with horizontal features to thousands of kilometers below the F-peak that have been observed moving from higher to lower latitudes (Chan and Villard, 1962) with characteristics of gravity waves (Thome, 1968). Their sources are believed to be heat and momentum deposited in the atmosphere in auroral regions by particle precipitation and Joule currents. These large scale structures are outstanding features that may play an important role in distributing energy and momentum over extensive distances. They may also be related to equatorial phenomena through cascading, such as bubbles and spread-F (Basu and Kelley, 1977). Smaller scale features with scales from tens to a few hundred kilometers are believed to arise from more local sources because of their attenuation with distance, such as meteorologically active regions. These medium scale structures are also capable of modifying the ionosphere along the field lines from one hemisphere to the other, as was shown by Gross and Muldrew (1984). Incoherent scatter radars observe TID's above and below the F-peak. These equipments have observed various scale structures.

Observations over wide regions are possible from satellites. The structures above the F-peak have been extensively measured by the Alouette and ISIS satellites using topside sounders. Unlike in situ instrumentations, ionization is measured over the entire altitude range from the satellite to close to the F-peak. Thus, one could determine the nature of large and medium scale structures over this entire range. A two-dimensional description of the structures would be possible, in contrast with the single track, one-dimensional measurements of in situ instrumentation, that should lead to a much improved understanding of the disturbances above the F-peak. It is also possible to relate them to the region below the F-peak by correlation with measurements of ground facilities, and with other satellites at altitudes below 300 km when their paths cross. An example of one such conjunction of ISIS 2 and AE-C, the first at high altitudes, the second below the F-peak, was treated in a paper written under this grant.

Prior to the work done under this grant, there was little, if any, study of data from the topside sounders for large scale structures. It was the purpose of the grant to make such studies and to look for more geophysical phenomena associated with large, medium and small structures as well.

## II. Details of the Research Efforts

Both Alouette 1 and ISIS 2 were in nearly circular orbits; Alouette 1 at about 1000 km altitude and ISIS 2 at 1400 km. Both carried a swept frequency sounder. Ionograms from their measurements are utilized to obtain the electron density profile below to nearly the F-region peak density level. Their sounders were capable of complete sweeps as follows: 18 seconds for Alouette 1 and 14 seconds for ISIS 2 (0.1-10 MHz sweep) or 22 seconds for the longer sweep. By taking a sequence of ionograms, contours of constant electron density may be obtained in which altitude is plotted as a function of universal time in minutes. The altitude is that at which the chosen electron density was observed to occur. One may also replace the time along the abscissa by the equivalent distance along the orbit. These iso-electronic contours are two-dimensional cuts in the vertical plane containing the satellite of the structure of the topside of the ionosphere. When wave structures are present of size greater than twice the distance traveled during the sweep time interval, about 200 km to 300 km (velocity of spacecraft divided by the Nyquist frequency), they may be evident in the record. Thus, the iso-electronic contours are useful for studying large scale structures, particularly those that propagate over large distances. Examples of the use of these structures and methods of analyzing them are given in a paper entitled "Large Scale Wave Structures from Topside Sounding" which was presented at the Ionospheric Effects Symposium in Arlington, Virginia, May 3-5, 1984, and published in a special issue of Radio Science in May-June 1985, as well as the Proceedings of the Symposium.

Smaller scale and medium sized structures of the order of one to a few hundred kilometers may also be found in swept and fixed frequency ionograms. Examples of equally spaced duct structures with spacings from about 30 to 70 km, found from this work, may be seen in a paper published by Gross and Muldrew in the October 1984 issue of the Journal of Geophysical Research. These structures were found and followed from ionogram to ionogram, and it was discovered that they extend in sheets as wide as about 400 km in the east-west direction and across the equator to the opposite hemisphere. Such transequatorial structures were found only at low latitudes, whereas it is not known whether structures found at mid-latitudes extend to the opposite hemisphere, because of the difficulty of obtaining data in the conjugate mid-latitude region.

A mechanism for creating these multiple smaller scale duct structures was proposed in a paper by Kuo, Gross and Lee entitled "Acoustic-Gravity-Wave-Produced Field-Aligned Irregularities" as a result of the observations. It was presented at the January 1984 meeting of URSI in Boulder, Colorado. This mechanism entails an instability arising from the presence of a gravity wave in the E region (F region was found to be unlikely) and from collisions between particles. A field-aligned purely growing wave and an oscillatory quasi-ion wave are parametrically excited by the gravity wave as a pump.

Another paper stemming from the multiple duct observations was also presented at that URSI meeting. It was a paper by Muldrew and Gross entitled "Characteristics of Grouped Ionization Ducts." In that paper it was shown that

many characteristics observed for bubbles, spread-F and single ducts were also characteristics of multiple ducts.

Sources for waves may not only occur in auroral regions. It is known, for example, that meteorological activity and volcanic eruptions produce waves. In addition, sources may exist in the thermosphere at low latitudes during magnetically active periods. Examples were given in a paper presented at the International Symposium on Equatorial Aeronomy in Hong Kong in March 1984. The paper is entitled "Unusual Heating Events at 250 km Altitude at Very Low Latitudes Seen by AE-E." It was published in a special issue of the Journal of Atmospheric and Terrestrial Physics, in 1985 (vol. 47, pp. 941-944).

Another connected paper entitled "Global Large Scale Structures in the F Region" was presented by Prof. Gross at the Goddard Workshop on Thermosphere Dynamics II in Calverton, Maryland, Oct. 3-5, 1984. An earlier version of this work was published in the Journal of Geophysical Research in January, 1985.

The methods of analysis are described in the papers referred to and others in the publications of Prof. Gross. Software for the ISIS data was written under this program.

## References

1. S. Basu and M.C. Kelley (1977), "Review of Equatorial Scintillation Phenomena in the Light of Recent Developments in the Theory and Measurement of Equatorial Irregularities," *J. Atmos. Terr. Phys.*, **39**, 1229-1242.
2. K.L. Chan and O.G. Villard (1962), "Observation of Large-Scale Traveling Ionospheric Disturbances by Spaced-Path High Frequency Instantaneous Frequency Measurements," *J. Geophys. Res.*, **67**, 973-988.
3. P.L. Dyson, J.P. McClure and W.B. Hanson (1974), "In situ Measurements of the Spectral Characteristics of F-Region Ionospheric Irregularities," *J. Geophys. Res.*, **79**, 1497-1502.
4. R.W. Fredericks and W.W.L. Taylor (1981), "Waves in Space Plasmas Program," Paper 6-1, Proceedings of the Symposium on the Effect of the Ionosphere on Radiowave Systems. Sponsored by NRL, ONR and AFGL, April 14-16, 1981, Alexandria, Va.
5. S.H. Gross (1984), "Global Large-Scale Structures in the F Region," *J. Geophys. Res.*, 1985. (See EOS, 10/16/84 GAP.)
6. S.H. Gross and D.B. Muldrew (1984), "Uniformly Spaced Field-Aligned Ionization Ducts," *J. Geophys. Res.*, **89**, 8986-8996.
7. S.H. Gross, C.A. Reber and F. Huang (1980), "Large-Scale Waves in the Ionosphere Observed by the AE Satellites," Ref. 29 in AGARD Conference Proceedings No. 295, The Physical Basis of the Ionosphere in the Solar-Terrestrial System.
8. S.H. Gross, C.A. Reber and F. Huang (1984), "Large-Scale Waves in the Thermosphere Observed by the AE-C Satellite," *IEEE Trans. Geosci. Rem. Sens.*, **GE-22**, 340-352.
9. S.H. Gross, F. Huang (1984), "Medium-Scale Gravity Waves in the Thermosphere Observed by the AE-C Satellite," *IEEE Trans. Geosci. Rem. Sens.*, March 1985.
10. G.H. Munro (1950), "Traveling Disturbances in the Ionosphere," *Proc. Roy. Soc.*, **A202**, 208-223.
11. C.A. Rever, A.E. Hedin, D.T. Pelz, N.E. Potter and L.H. Brace (1975), "Phase and Amplitude Relationships of Wave Structure Observed in the Lower Thermosphere," *J. Geophys. Res.*, **80**, 4576-4580.
12. G.D. Thome (1968), "Long-Period Waves Generated in the Polar Ionosphere During the Onset of Magnetic Storms," *J. Geophys. Res.*, **73**, 6319-6336.